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भारतीय मानक

प्रकाशिक तंतु केबल

भाग 1 सामान्य विशिष्टि

Indian Standard

OPTICAL FIBRE CABLES

PART 1 GENERIC SPECIFICATION

UDC 621·315·2 : 681·7·068

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Price Group 12

Fibre Optics Sectional Committee, LTD 27

NATIONAL FOREWORD

This Indian Standard, which is identical with IEC Pub 794-1 : 1993 'Optical fibre cables : Part 1 Generic specification' issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of the Fibre Optics Sectional Committee, LTD 27 and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

CROSS REFERENCES

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 68-2-14 Environmental testing, Part 2 Tests — Test N : Change of temperature	IS 9000 (Part 14/Sec 1-3) : 1988 Basic environmental testing procedures for electronic and electrical items : Part 14 Test N : Change of temperature	Technically equivalent

The Technical Committee responsible for preparation of this standard has reviewed the provisions of the following international publications referred to in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

IEC 68-1 : 1988 Environmental testing, Part 1 : General and guidance
IEC 68-2-10 : 1988 Environmental testing, Part 2 : Tests — Test J and guidance : Mould growth
IEC 189-1 : 1986 Low-frequency cables and wires with PVC insulation and PVC sheath, Part 1 General test and measuring methods
IEC 227-2 : 1979 Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V. Part 2 : Test methods
IEC 332 : Test on electric cables under fire conditions
IEC 540 : 1982 Test methods for insulations and sheaths of electric cables and cords (elastomeric and thermoplastic compounds)
IEC 793-1 : 1992 Optical fibres, Part 1 Generic specification
IEC 811 : Common test methods for insulating and sheating materials of electric cables
IEC 874-1 : 1987 Connectors for optical fibres and cables, Part 1 : Generic specification

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

IS 13882 (Part 1) : 1993
IEC Pub 794-1 : 1993

Indian Standard

OPTICAL FIBRE CABLES

PART 1 GENERIC SPECIFICATION

SECTION 1: GENERAL

1.1 Scope and object

This part of International Standard IEC 794 applies to optical fibre cables for use with telecommunication equipment and devices employing similar techniques and to cables having a combination of both optical fibres and electrical conductors.

The object of this part is to establish uniform requirements for the geometrical, transmission, mechanical and climatic characteristics of optical fibre cables, and electrical requirements where appropriate.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 794. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 794 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 68-1: 1988, *Environmental testing. Part 1: General and guidance*

IEC 68-2-10: 1988, *Environmental testing. Part 2: Tests – Test J and guidance: Mould growth*

IEC 68-2-14: 1984, *Environmental testing. Part 2: Tests – Test N: Change of temperature*

IEC 189-1: 1986, *Low-frequency cables and wires with PVC insulation and PVC sheath. Part 1: General test and measuring methods*

IEC 227-2: 1979, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V. Part 2: Test methods*

IEC 332: *Tests on electric cables under fire conditions*

IEC 540: 1982, *Test methods for insulations and sheaths of electric cables and cords (elastomeric and thermoplastic compounds)*

IEC 793-1: 1992, *Optical fibres. Part 1: Generic specification*

IEC 811: *Common test methods for insulating and sheathing materials of electric cables*

IEC 874-1: 1987, *Connectors for optical fibres and cables. Part 1: Generic specification*

1.3 Definitions

Under consideration.

1.4 Optical fibre cables

Optical fibre cables, containing optical fibres and possibly electrical conductors, consist of the following types:

1.4.1 *Cables for direct burial*

1.4.2 *Cables for installation in ducts or tunnels*

1.4.3 *Overhead cables*

1.4.4 *Underwater cables (cables for relatively short water crossings)*

1.4.5 *Indoor cables*

1.4.6 *Portable cables*

1.4.7 *Equipment cables*

1.4.8 *Special purpose cables*

1.4.9 *Submarine cables*

1.5 Materials

1.5.1 *Optical fibre material*

Optical fibres shall be uniform in quality and their characteristics shall meet the requirements of IEC 793-1.

1.5.2 *Electrical conductors*

Any electrical conductors shall be uniform in quality and free from defects. Their characteristics shall be in accordance with the relevant IEC standards as stated in the detail specification.

1.5.3 *Other materials*

Material used in the construction of optical fibre cables shall be compatible with the physical and optical properties of the fibres and shall be in accordance with the relevant IEC standards as stated in the detail specification.

1.6 Cable construction

The construction, dimensions, weight, mechanical, optical, electrical and climatic properties of each type of optical fibre cable shall be as stated in the relevant detail specification.

SECTION 2: MEASURING METHODS FOR DIMENSIONS

2.1 Object

The dimensions of the optical fibres, electrical conductors and cables shall be determined by subjecting samples to tests selected from table 1. The tests applied, acceptance criteria and number of samples shall be as stated in the detail specification.

Table 1 – Measuring methods for dimensions

Test method	Test	Characteristics covered by test method
IEC 793-1-A1 IEC 793-1-A1B	Refracted near field Transverse interference method	Diameter of core Diameter of cladding Non-circularities Concentricity errors
IEC 793-1-A2	Near field light distribution	Diameter of core Diameter of cladding Diameter of primary coating Diameter of buffer Non-circularities Concentricity errors
IEC 793-1-A3	Four concentric circles	Diameter of core Diameter of cladding Non-circularities Concentricity errors
IEC 793-1-A4	Mechanical diameter measurement	Diameter of cladding Diameter of primary coating Diameter of buffer Non-circularities
IEC XXX-1-A5	Mechanical length measurement (under consideration)	Length of cable
IEC 793-1-A6	Delay of transmitted and/or reflected pulse	Length of cable
IEC 793-1-C1C	Backscattering technique	Length of fibre
IEC 189[1]	Mechanical	Diameter of electrical conductor
IEC 540[2] IEC 189[1]	Mechanical	Thickness of insulation Thickness of sheaths Overall dimensions

1 Low-frequency cables and wires with p.v.c. insulation and p.v.c. sheath.

2 Test methods for insulations and sheaths of electric cables and cords (elastomeric and thermoplastic compounds).

SECTION 3: MEASURING METHODS FOR MECHANICAL CHARACTERISTICS

3.1 Object

This section describes measuring methods applying to mechanical tests of optical cables. The methods are to be used for inspection of optical fibre cables for commercial purposes.

The mechanical characteristics of optical fibre cables shall be verified by subjecting samples to tests selected from table 2. The tests applied, acceptance criteria and number of samples shall be as laid down in the detail specification.

NOTE - Not all tests are applicable to all cables.

Table 2 – Measuring methods for mechanical characteristics

Test method	Test	Characteristics covered by test method
IEC 794-1-E1 IEC XXX-1-E2 IEC 794-1-E3 IEC 794-1-E4 IEC XXX-1-E5	Tensile performance Abrasion (under consideration) Crush Impact Isostatic pressure (under consideration)	Mechanical strength
IEC 794-1-E6 IEC 794-1-E7 IEC 794-1-E8 IEC 794-1-E9 IEC 794-1-E10 IEC 794-1-E11	Repeated bending Torsion Flexing Snatch Kink Bend	Ease of handling

3.2 Operational definitions

Under consideration.

3.3 Method IEC 794-1-E1 – Tensile performance

3.3.1 *Object*

This measuring method applies to optical fibre cables which are tested at a particular tensile strength in order to examine the behaviour of the attenuation as a function of the load on a cable which may occur during installation, for example pulling the cable around corners. This method is intended to be non-destructive (the tension applied shall be within the operational values).

3.3.2 *Sample preparation*

A length of cable under test sufficient to achieve the desired accuracy is removed from the reel or ring without cutting.

3.3.3 *Apparatus*

a) Attenuation measuring apparatus for determination of attenuation change.

(See IEC 793-1, Section Four – Measuring methods for transmission and optical characteristics.)

b) 1) Tensile strength measuring apparatus which is able to pick up the minimum length to be tested (see figure 1).

2) Tensile power device with a maximum error of ±3 % .

3) Chuck drums with appropriate core diameter or equivalent system. Transfer device with appropriate diameter can be used to shorten the equipment.

c) An example of suitable apparatus is shown in figure 1.

It shall be checked that the distance between the transfer devices and also the diameters of the transfer devices are such that they do not affect the test conditions.

3.3.4 *Procedure*

a) The test is carried out at ambient temperature.

b) The tension shall be continuously increased to the required value given in the detail specification.

c) The change of attenuation shall be recorded preferably as a continuous function of load.

d) In case of cables with a large number of fibres a multiple attenuation measuring device can be used.

e) A representative number of fibres and/or a number of test cycles have to be agreed between manufacturer and customer.

3.3.5 *Results*

a) Final measurements

The attenuation of the sample shall not exceed the values given in the relevant detail specification.

b) The following data shall be presented with the results:

1) Length of the cable and length under tension.
2) End preparation.
3) Test data of the tension device.
4) Test data of the launching conditions and attenuation measuring device.

5) Severity of test.
6) Change of attenuation at a specified wavelength as a function of the load.

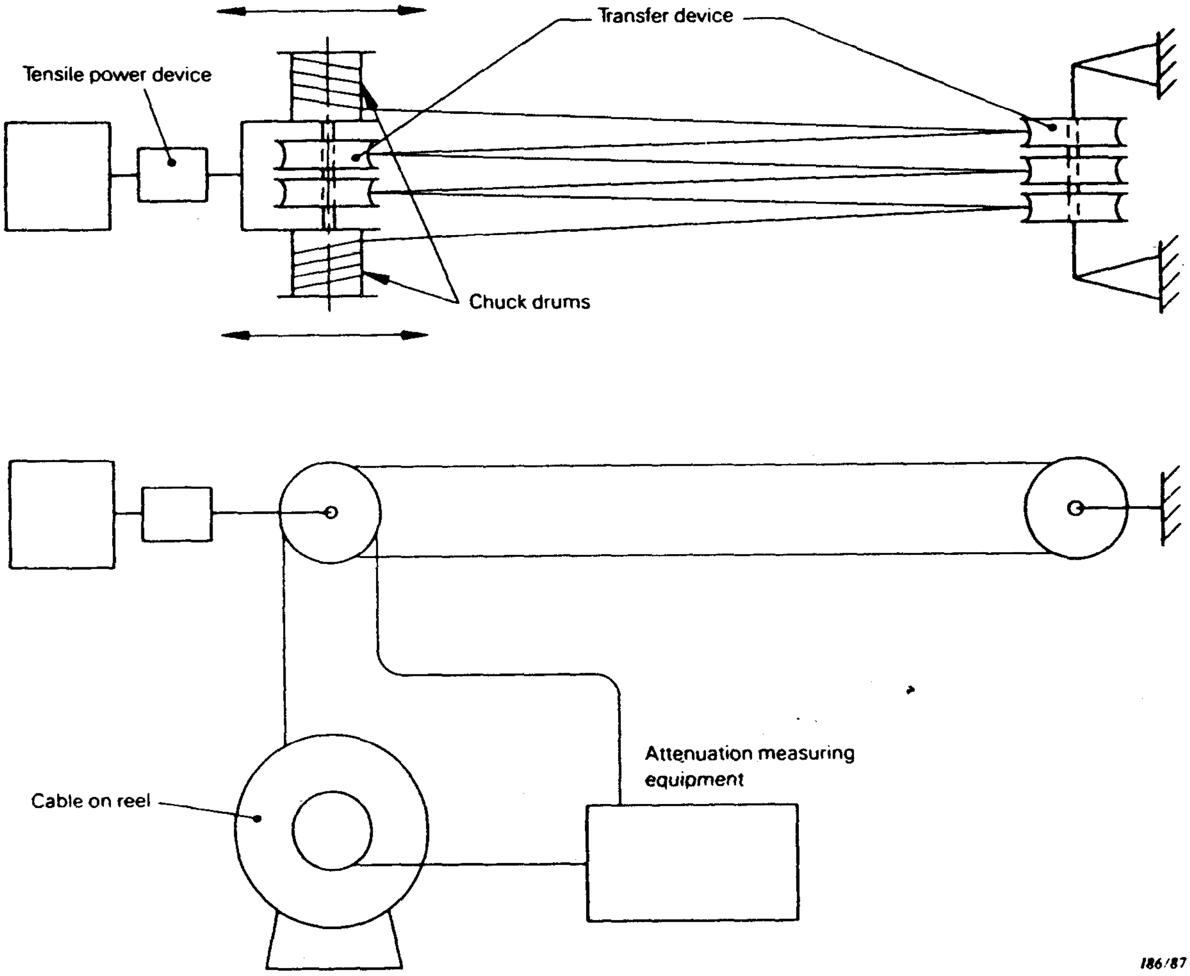


Figure 1 – Example of a tensile performance measuring equipment

3.4 Method IEC XXX-1-E2 – Abrasion

Under consideration.

3.5 Method IEC 794-1-E3 – Crush

3.5.1 *Object*

The purpose of this test is to determine the ability of an optical fibre cable to withstand crushing.

3.5.2 *Apparatus*

The apparatus shall allow a sample of cable to be crushed between a flat steel base plate and a movable steel plate which applies the crushing force uniformly over a 100 mm length of the sample. The edges of the movable plate shall be rounded with an adequate radius. A suitable apparatus is shown in figure 2.

3.5.3 *Conditions for testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

3.5.4 *Procedure*

The cable sample shall be mounted between the plates so that lateral movement is prevented, and the load applied gradually without any abrupt change. If the load is applied in incremental steps, these shall not exceed a ratio of 1,5: 1.

The total load and duration of application shall be specified in the detail specification.

3.5.5 *Requirement*

The acceptance criteria for the test shall be stated in the detail specification.

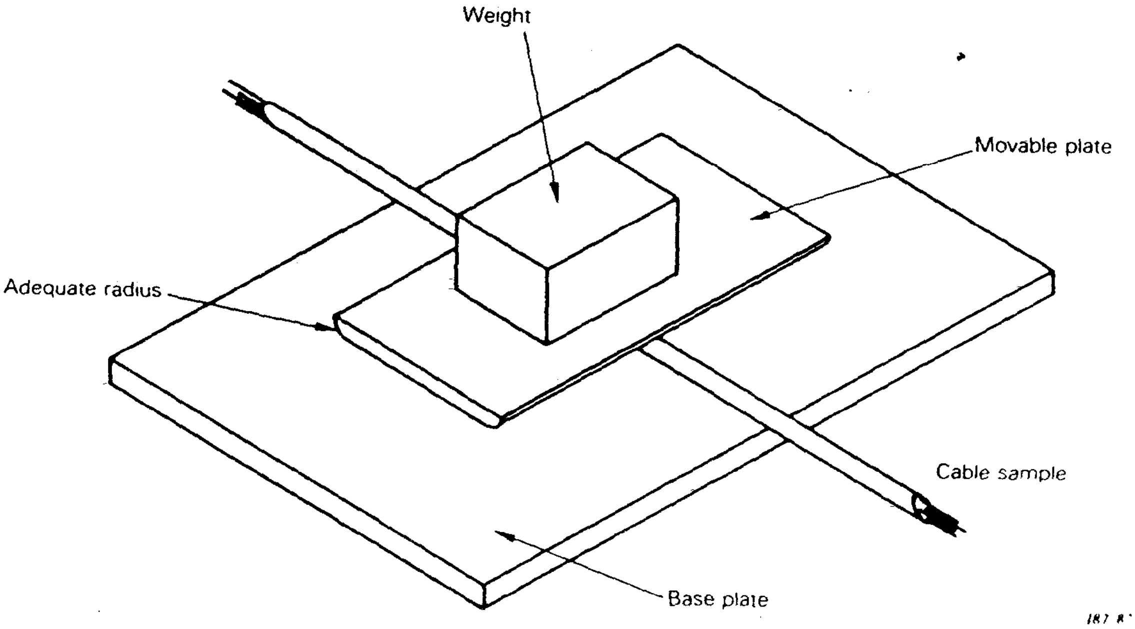


Figure 2 – Crush test

3.6 Method IEC 794-1-E4 – Impact

3.6.1 *Object*

The purpose of this test is to determine the ability of an optical fibre cable to withstand impact.

3.6.2 *Apparatus*

The apparatus shall permit a weight to drop vertically onto a piece of steel which transmits the impact to the cable sample which is fixed to a flat substantial steel base.

A suitable apparatus is shown in figure 3, but other equivalent apparatus may also be used. The surface of the intermediate piece in contact with the sample shall be rounded. The radius *R* of the surface shall be specified in the detail specification.

3.6.3 *Conditions for testing*

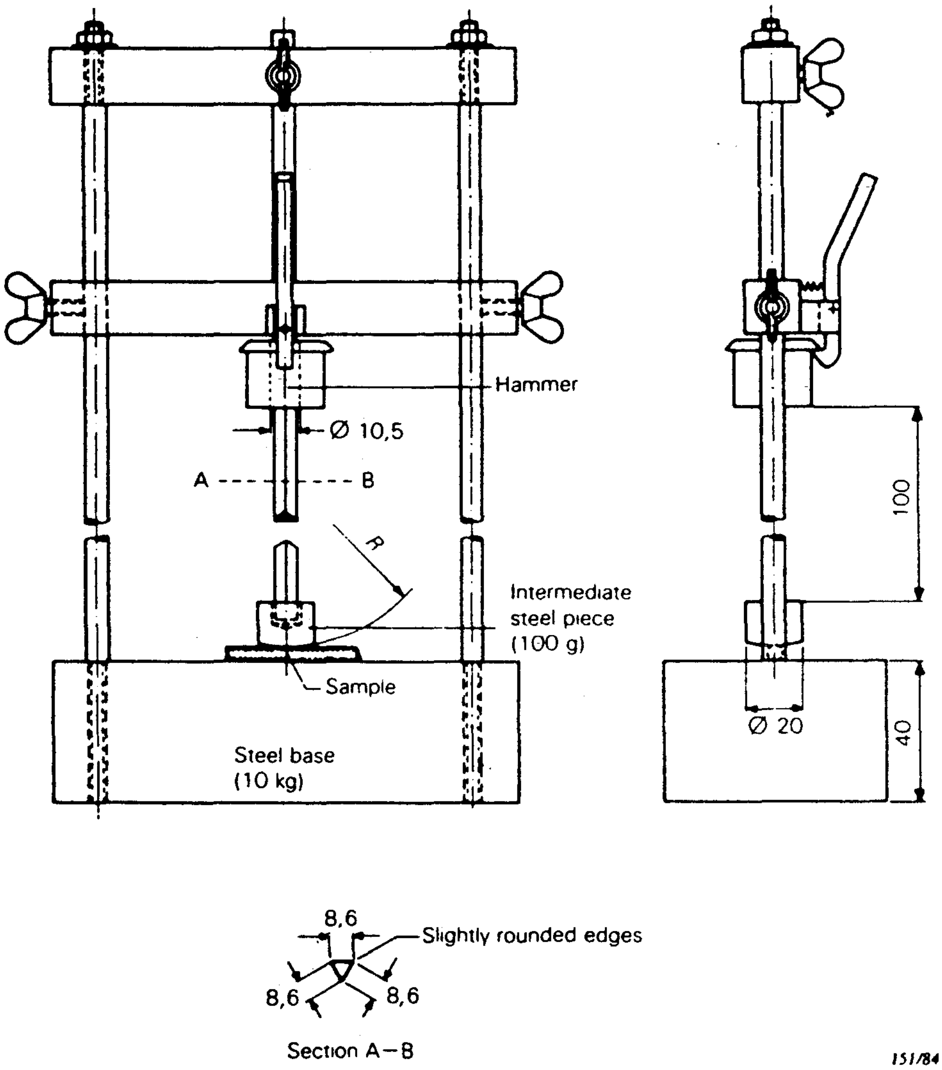
The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1 or 9.5.6 of IEC 540.

3.6.4 *Procedure*

The mass of the weight and the height from which the weight falls shall be adjusted to give the value of starting energy shown in the detail specification. The number of impacts shall be as specified in the detail specification.

3.6.5 *Acceptance criteria*

The acceptance criteria for the test shall be stated in the detail specification.



Dimensions in millimetres

Figure 3 – Impact test

3.6.6 *Impact test*

This test shall be carried out in accordance with clause 9 of IEC 540, at the temperature shown in the detail specification.

In addition to the requirement of 9.5.6 of IEC 540, no fibre shall break during the test.

3.7 Method IEC XXX-1-E5 – Isostatic pressure

Under consideration.

3.8 Method IEC 794-1-E6 – Repeated bending

3.8.1 *Object*

The purpose of this test is to determine the ability of an optical fibre cable to withstand repeated bending.

3.8.2 *Preparation of sample*

The sample shall be terminated at each end in a connector, or in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner.

3.8.3 *Apparatus*

The apparatus shall enable the sample to be bent backwards and forwards through 180°, the two extreme positions making an angle of 90° on both sides of the vertical, whilst being subjected to a tensile load. For testing cable a suitable apparatus is shown in figure 4. For testing cable/connector assemblies, a suitable apparatus is shown in figure 5. Other equivalent apparatus may be used.

3.8.4 *Conditions for testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

3.8.5 *Procedure*

The sample shall be fixed to the apparatus as shown in figures 4 and 5 and loaded with a weight. The mass of the weight, bending radius R and dimension L shall be as shown in the detail specification. The sample shall be bent backwards and forwards, the two extreme positions making an angle of 90° on both sides of the vertical. Displacing the sample from the vertical position to the extreme right position then oscillating to the extreme left position and returning to the original vertical position is considered to be one cycle. The bending rate shall be approximately one cycle in 2 s. The number of cycles and values of *a*, *b* and *c* shall be as specified in the detail specification.

3.8.6 *Requirement*

During the test no fibre shall break. The acceptance criteria for the test shall be stated in the detail specification.

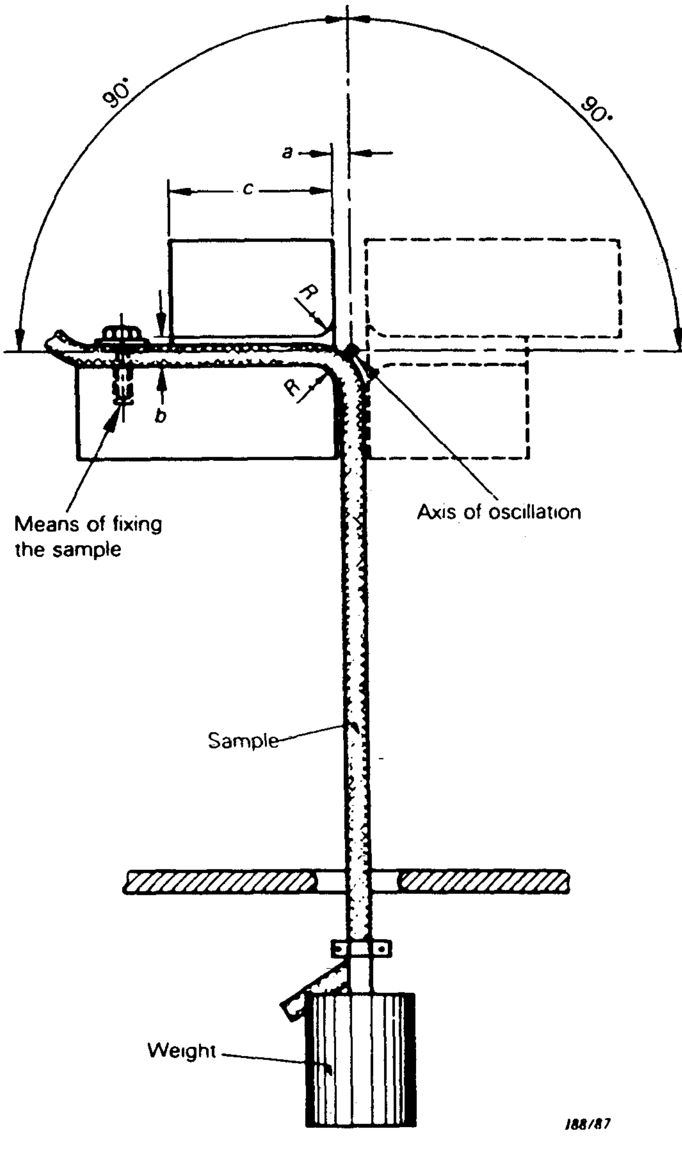


Figure 4 – Cable test

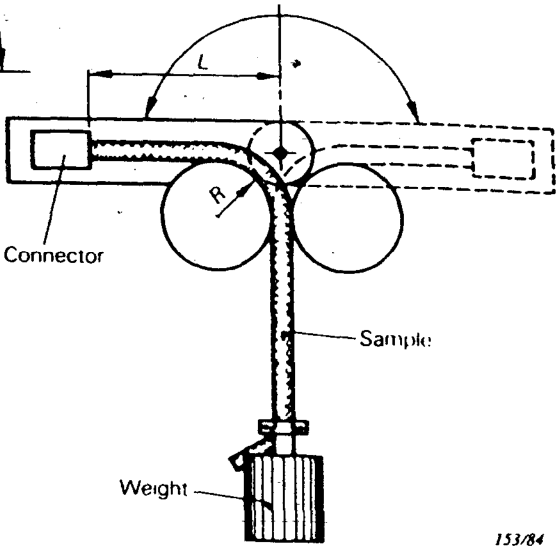


Figure 5 – Cable/connector assembly test

3.9 Method IEC 794-1-E7 – Torsion

3.9.1 *Object*

The purpose of this test is to determine the ability of an optical fibre cable to withstand torsion.

3.9.2 *Preparation of sample*

The sample shall be terminated in a connector, or in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner.

3.9.3 *Apparatus*

The test shall be carried out by means of an apparatus consisting of a fixed clamp and a rotating clamp. Suitable apparatus is shown in figure 6 and in figure 7, but other substantially equivalent apparatus may also be used.

3.9.4 *Conditions of testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

3.9.5 *Procedure*

The sample shall be mounted in the test apparatus with the cable clamped in the fixed clamp sufficiently tight to prevent movement of the cable sheath during the test. The connector or termination shall be fixed to the rotating clamp, which shall be rotated in a clockwise direction for the number of turns given in the detail specification. The sample shall then be returned to the starting position and then rotated in an anti-clockwise direction for the same number of turns and returned to the starting position. This complete movement constitutes one cycle. The length of sample tested, the mass of the weight and the number of cycles shall be as specified in the detail specification.

3.9.6 *Requirement*

The acceptance criteria for the test shall be stated in the detail specification.

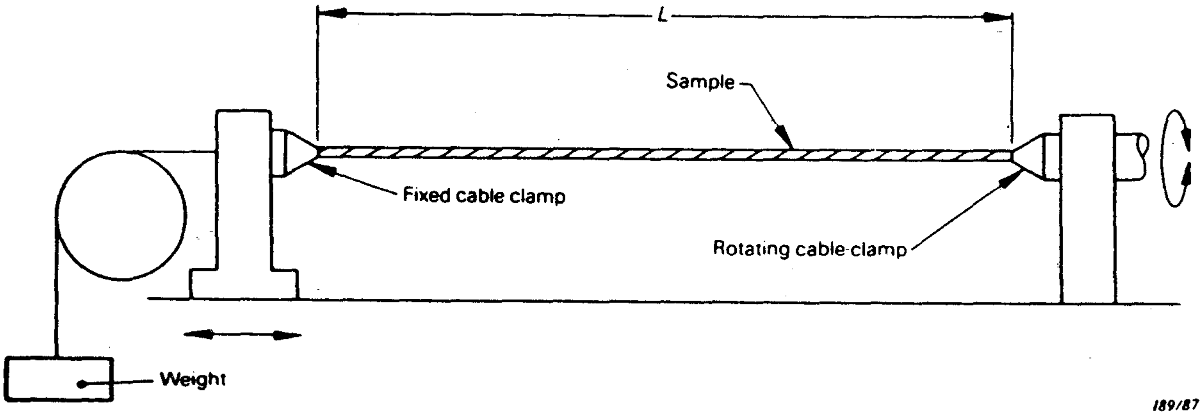


Figure 6 – Torsion test

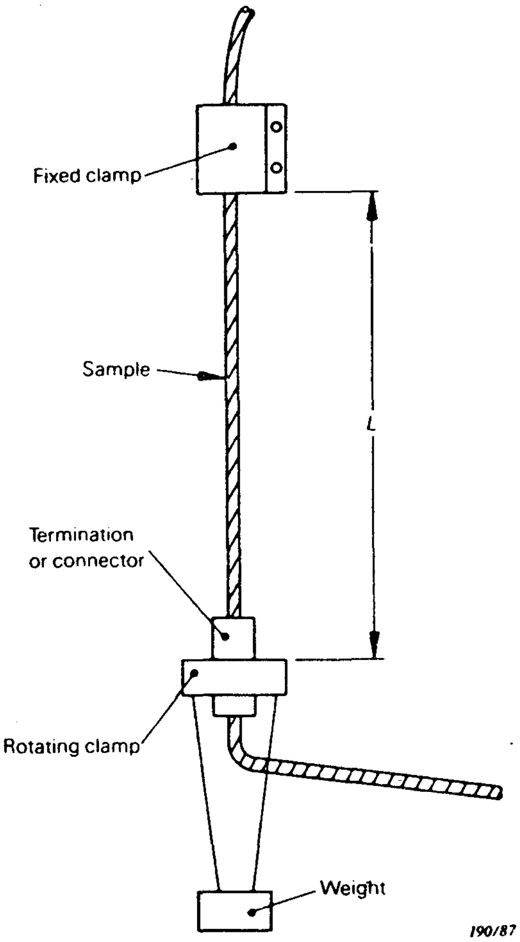


Figure 7 – Torsion test

3.10 Method IEC 794-1-E8 – Flexing

3.10.1 *Object*

The purpose of this test is to determine the ability of an optical fibre cable to withstand repeated flexing.

3.10.2 *Preparation of sample*

The sample shall be terminated at each end in a connector, or in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner.

3.10.3 *Apparatus*

The test is carried out in accordance with IEC 227-2 unless otherwise required by the detail specification.

The pulleys shall have a semicircular shaped groove for circular cables and a flat groove for flat cables. The restraining clamps D shall be fixed so that the pull is always applied by the weight from which the carrier is moving away. Equivalent apparatus may be used.

3.10.4 *Conditions for testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

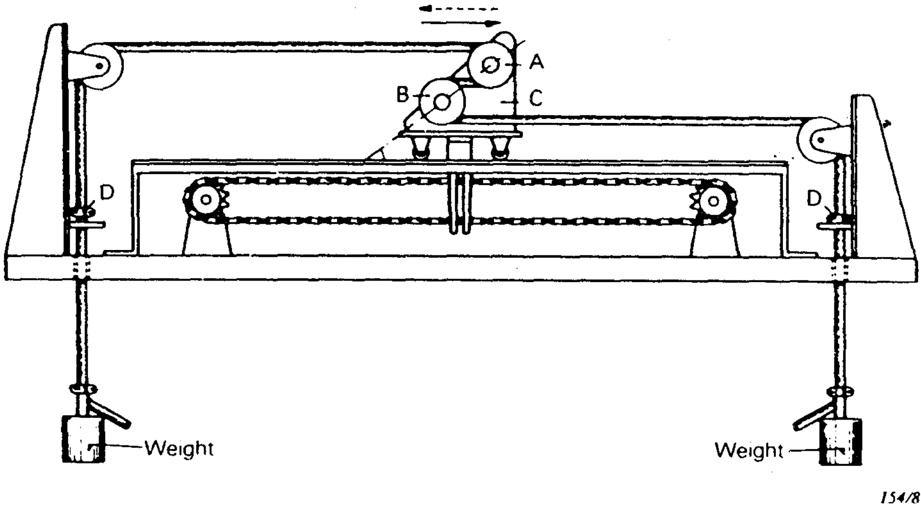
3.10.5 *Procedure*

The sample shall be stretched over the pulleys as shown in figure 8, each end being loaded with a weight. The mass of this weight and the diameter of the pulleys A and B shall be as specified in the detail specification.

The sample shall be flexed for the number of cycles specified in the detail specification.

3.10.6 *Requirement*

The acceptance criteria for the test shall be stated in the detail specification.



A and B = pulleys
C = carrier
D = restraining clamps

Figure 8 – Flexing apparatus

3.11 Method IEC 794-1-E9 – Snatch

3.11.1 *Objet*

The purpose of this test is to determine the ability of an optical fibre cable to withstand a sudden snatch load.

3.11.2 *Preparation of sample*

The sample shall be terminated in a connector, or in a manner such that the fibres, sheathing and any strain members are clamped together in a representative manner.

3.11.3 *Apparatus*

A hook of dimensions as shown in figure 9 shall have a shaft capable of bearing variable loads applied to it. The radius of that part of the hook coming into contact with the cable shall be greater than the radius of the cable. In addition, the hook shall be so constructed that it shall not distort during the test.

3.11.4 *Conditions for testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

3.11.5 *Procedure*

The cable shall be clamped firmly between two rigid supports, forming a catenary of 4,5 m horizontal span and 300 mm sag.

After assembling the catenary, the attenuation shall be measured.

The hook with the mass attached shall be held or supported over the cable, so that the crown of the hook is centred over the lowest point of the cable at a height of 100 mm.

The mass shall be as specified in the detail specification. The hook is then released so as to catch the cable, after which the attenuation shall be re-examined. The mass shall be removed from the cable, and if required by the detail specification the attenuation shall be measured again. This constitutes one cycle. The number of cycles to be applied shall be as specified in the detail specification.

3.11.6 *Requirements*

During the test, no fibre shall break and electrical continuity if applicable shall be maintained. During the test, the attenuation may be monitored. After the test any increase in attenuation shall be checked if required.

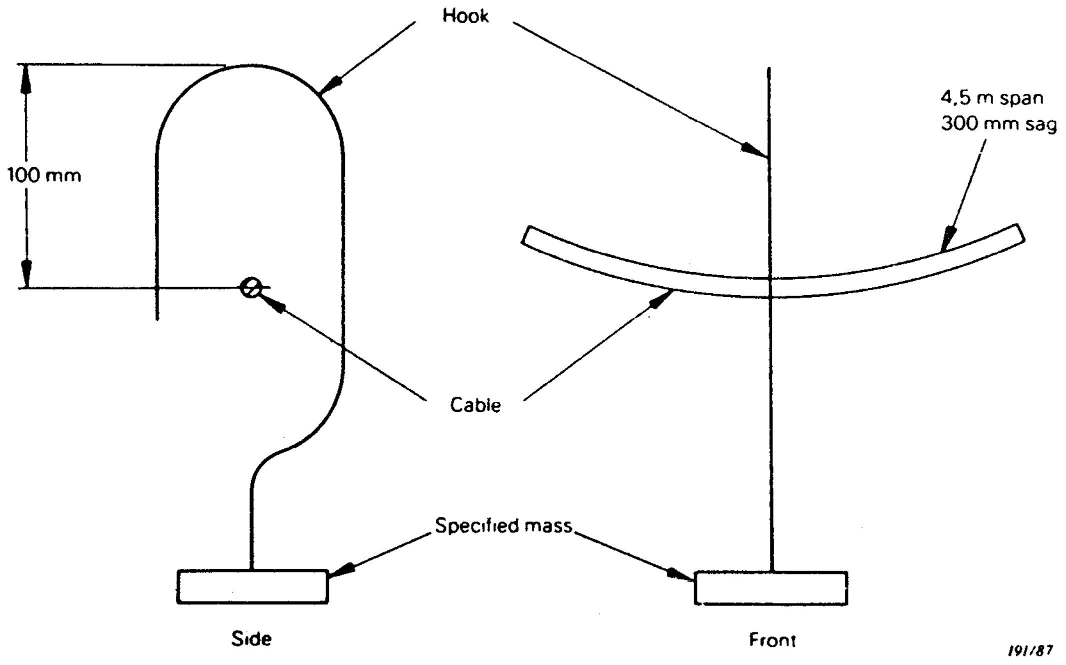


Figure 9 – Snatch test

3.12 Method IEC 794-I-E10 – Kink

3.12.1 *Object*

The purpose of this test is to verify whether kinking of an optical cable results in breakage of any optical fibre in the cable. Depending on the rigidity of the cable sheath, fibre breakage can occur when a loop is formed of dimension small enough to induce a kink in the sheath.

3.12.2 *Sample*

A length of about 10 times the minimum bending radius of the cable shall be taken.

3.12.3 *Procedure*

The sample shall be held in both hands. A loop ① shall be made (see figure 10). The diameter of the loop shall be reduced to the minimum value as specified in the detail specification by pulling slowly on the two end ②. The forces at the bottom of the loop shall be applied in one plane.

The temperature of the sample is given in the detail specification.

3.12.4 *Requirement*

No kink ③, as shown in figure 10, shall occur.

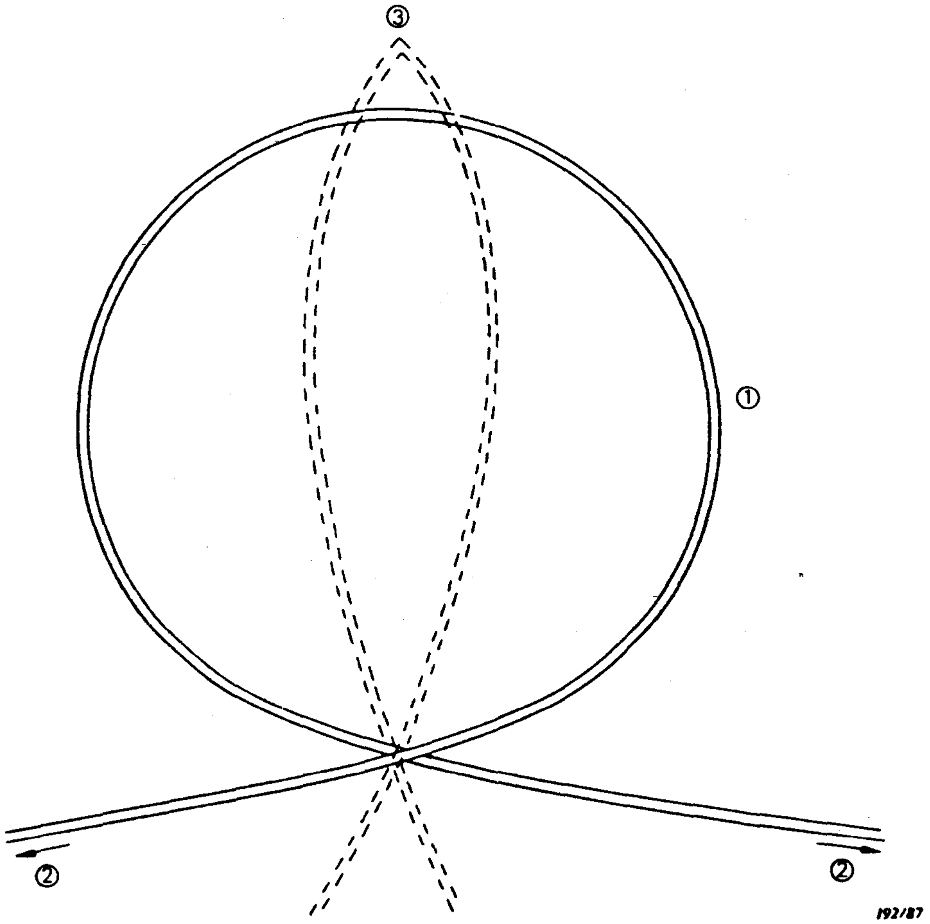


Figure 10 – Kink test

3.13 Method IEC 794-1-E11 – Cable bend

3.13.1 *Object*

The purpose of this test is to determine the ability of a small diameter optical fibre cable to withstand bending around a test mandrel.

3.13.2 *Preparation of sample*

The sample shall be terminated at each end in a connector, or in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner.

3.13.3 *Apparatus*

A single mandrel apparatus shall enable the sample to be wrapped tangentially in a close helix around a test mandrel.

3.13.4 *Conditions for testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with 5.3 of IEC 68-1.

3.13.5 *Procedure*

Depending on the cable construction and diameter, and as indicated in the detail specification, one of the following two procedures shall be used:

Procedure 1

The sample shall be wrapped in a close helix around the mandrel at a uniform rate of one revolution in about 5 s. Sufficient tension shall be applied to ensure that the sample contours the mandrel. The sample shall then be unwrapped.

A cycle consists of wrapping and unwrapping.

The diameter of the test mandrel, the number of turns per helix and the number of cycles shall be shown in the detail specification.

Procedure 2

The sample shall be bent around a mandrel through 180° (U-bend) and kept taut during the bending. A cycle consists of one U bend followed by a reverse U bend. The diameter of the test mandrel and the number of cycles shall be stated in the detail specification.

3.13.6 *Requirement*

During the test no fibre shall break. The sheath shall not show any crack visible to the naked eye when examined whilst still wrapped on the mandrel. If relevant, any permanent increase in attenuation after the test shall not exceed the value specified in the detail specification.

3.13.7 *Cable bend test at low temperature*

This test shall be carried out in accordance with 9.1 of IEC 540, at the temperature specified in the detail specification.

In addition to the requirement of 9.1.6 of IEC 540, no fibre shall break during the test.

SECTION 4: MEASURING METHODS FOR TRANSMISSION AND OPTICAL CHARACTERISTICS

4.1 Object

The transmission and optical characteristics of optical fibre in cables shall be verified by carrying out selected tests from those shown in table 3. The tests applied and acceptance criteria shall be as specified in the detail specification.

Table 3 – Transmission and optical characteristics of optical fibres

Test methods of multimode and single-mode fibres		
Test method	Test	Characteristics covered by test method
IEC 793-1-C1A IEC 793-1-C1B IEC 793-1-C1C	Cut-back technique Insertion loss technique Backscattering technique	Attenuation
IEC 793-1-A1.A IEC 793-1-A1B IEC 793-1-A2	Refracted near field method Transverse interference method Near field light distribution	Relative index profile
IEC 793-1-C1C	Backscattering technique	Point defects
IEC 793-1-C4 IEC 793-1-C1C	Transmitted or radiated light power Backscattering technique	Optical continuity
IEC 793-1-C5A IEC 793-1-C5B	Phase shift method Spectral group delay measurement in the time domain	Chromatic dispersion
IEC 793-1-C10A IEC 793-1-C10B	Transmitted power monitoring Backscattering monitoring	Change of optical transmittance during mechanical and environmental tests

Test methods of multimode fibres		
Test method	Test	Characteristics covered by test method
IEC 793-1-C2A IEC 793-1-C2B	Impulse response Frequency response	Baseband response
IEC 793-1-C6	Far field distribution	Numerical aperture

Table 3 *(concluded)*

Test methods of single-mode fibres		
Test method	Test	Characteristics covered by test method
IEC 793-1-C3	Microbending sensitivity	Microbending sensitivity
IEC 793-1-C11	Macrobending sensitivity	Macrobending sensitivity
IEC 793-1-C5C IEC 793-1-C5D	Differential phase shift Interferometry (for future consideration)	Chromatic dispersion
IEC 793-1-C7A IEC 793-1-C7B	Cut-off wavelength measurement Cable cut-off wavelength measurement (under consideration)	Fibre cut-off wavelength Cable fibre cut-off wavelength
IEC 793-1-C9A IEC 793-1-C9B IEC 793-1-C9C IEC 793-1-C9D	Far field scan Variable aperture Near field scan Knife edge scan (for future consideration)	Mode field diameter

SECTION 5: MEASURING METHODS FOR ELECTRICAL CHARACTERISTICS

5.1 Object

When electrical conductors are incorporated in an optical fibre cable, verification of various electrical characteristics may be necessary. Typical tests are shown in table 4. The tests applied and the acceptance criteria shall be as laid down in the detail specification.

Table 4 – Measuring methods for electrical characteristics

Test method	Test	Characteristics covered by test method
IEC 189-1	Conductor resistance Dielectric strength of insulation Insulation resistance	Characteristics of insulated electrical conductors

SECTION 6: MEASURING METHODS FOR ENVIRONMENTAL CHARACTERISTICS

6.1 Object

This section describes measuring methods which apply to environmental tests of optical fibre cables. The methods are to be used for inspection of optical fibre cables.

The ability of optical fibre cables to meet environmental requirements without deterioration of their mechanical or optical properties shall be verified by subjecting samples to tests selected from table 5. The tests applied, the relevant temperatures and conditions, the number of samples, and acceptance criteria shall be as stated in the detail specification.

Table 5 – Measuring methods for environmental characteristics

Test method	Test	Characteristics covered by test method
IEC 794-1-F1	Temperature cycling	Climatic characteristics
IEC XXX-1-F2*	Contamination	Chemical resistance
Test J of IEC IEC 68-2-10	Mould growth	Biological resistance
IEC 332	Fire conditions	Cable performance under fire conditions
IEC 794-1-F3 IEC XXX-1-F4*	Sheath integrity External static pressure	Sheath defects
IEC 794-1-F5	Water penetration	Resistance to water penetration
IEC 189-1	Cold bend	Flexibility at low temperature
IEC XXX-1-F6*	Freezing	Resistance to freezing
IEC XXX-1-F7*	Nuclear radiation	Resistance to nuclear radiation

* Under consideration

6.2 Operational definitions

Under consideration.

6.3 Method IEC 794-1-F1 – Temperature cycling

6.3.1 *Object*

This measuring method applies to optical fibre cables which are tested by temperature cycling in order to determine the stability behaviour of the attenuation of a cable submitted to temperature changes.

Changes in the attenuation of optical fibre cables which may occur with changing temperatures are generally the result of buckling or tensioning of the fibres resulting from differences between their thermal expansion coefficient and the coefficients of the cable strength and jacketing members. Test conditions for temperature dependent measurements shall simulate the worst conditions.

This test can be used either for monitoring cable behaviour in the temperature range which may occur during storage, transportation and usage or to check, in a selected temperature range (usually wider than that required for the above-mentioned case), the stability behaviour of the attenuation connected to a substantially microbend-free situation of the fibre within the cable structure.

6.3.2 *Sample preparation*

The sample shall be a factory length or a sample of sufficient length as indicated in the detail specification but nevertheless of length appropriate to achieve the desired accuracy (see note).

In order to gain reproducible values, the cable sample shall be brought into the climatic chamber as a loose coil or on a reel.

NOTE - For example, it is recommended that the minimum length of fibre submitted to the test should be not less than 1 000 m for A1 and 2 000 m for B fibre.

The ability of the fibre(s) to accommodate differential expansion and contraction (for example by slipping within the cable) could be influenced by the bending radius of the cable, therefore sample conditioning should be realized as close as possible to normal usage conditions.

In the case of testing on a reel, the cable shall be wound up in such a way that all changes of cable characteristics (attenuation, length, etc.) which could occur in normal usage conditions are not altered.

Potential problems are due to an actual difference between the expansion coefficients of the test sample and the holder (reel, basket, plate, etc.) which can induce, during thermal cycles, a significant effect on the test result if "no effect" conditions are not completely fulfilled.

Parameters of influence are mainly: details of conditioning, type and material(s) of the holder, diameter of the sample coil or reel, etc.

General recommendations are the following:

- The winding diameter shall be large enough to keep the ability of the fibre to accommodate differential expansion and contraction. A winding diameter substantially greater than the value selected for cable delivery may be necessary.

- Any risk of cable expansion (or contraction) limitation created by conditioning shall be suppressed. In particular, special care should be taken to avoid remaining tension on the cable during the test. For example a tight winding on a drum is not recommended as it can limit cable contraction at low temperature. On the other hand, a tight multilayer winding can limit expansion at high temperature.

- The use of loose winding is recommended such as large diameter coils, bufferized reels with a soft layer or zero tension facility device, etc.

In order to limit the length of the cable under test, it is possible to connect several fibres of the cable and to measure the connected fibres. The number of connections shall remain limited and they should preferably be located outside the climatic chamber. Some care, however, should be taken in the interpretation of the results. For this purpose, the backscattering technique may help even if it is in no case considered as the recommended attenuation measurement method.

6.3.3 *Apparatus*

a) Appropriate attenuation measuring apparatus for determination of attenuation change.

See test methods of Section 4 of IEC 793-1.

b) Climatic chamber

The climatic chamber shall be of a suitable size to accommodate the sample (see **6.3.2**) and its temperature shall be controllable to remain within ±3 K of the specified testing temperature. One example of a suitable chamber is given in clause 2, test Nb, of IEC 68-2-14.

6.3.4 *Procedure*

a) Initial measurement

The sample shall be visually inspected and a basic value for attenuation at the initial temperature shall be determined.

Pre-conditioning conditions shall be agreed between customer and supplier.

b) Conditioning

1) The sample at ambient temperature shall be introduced into the climatic chamber which is also at that temperature.

2) The temperature in the chamber shall then be lowered to the appropriate low temperature T_A at the appropriate rate of cooling.

3) After temperature stability in the chamber has been reached, the sample shall be exposed to the low temperature conditions for the appropriate period t_1.

4) The temperature in the chamber shall then be raised to the appropriate high temperature T_B at the appropriate rate of heating.

5) After temperature stability in the chamber has been reached, the sample shall be exposed to the high temperature conditions for the appropriate period t_1.

6) The temperature in the chamber shall then be lowered to the value of the ambient temperature at the appropriate rate of cooling.

7) This procedure constitutes one cycle (see figure 11).

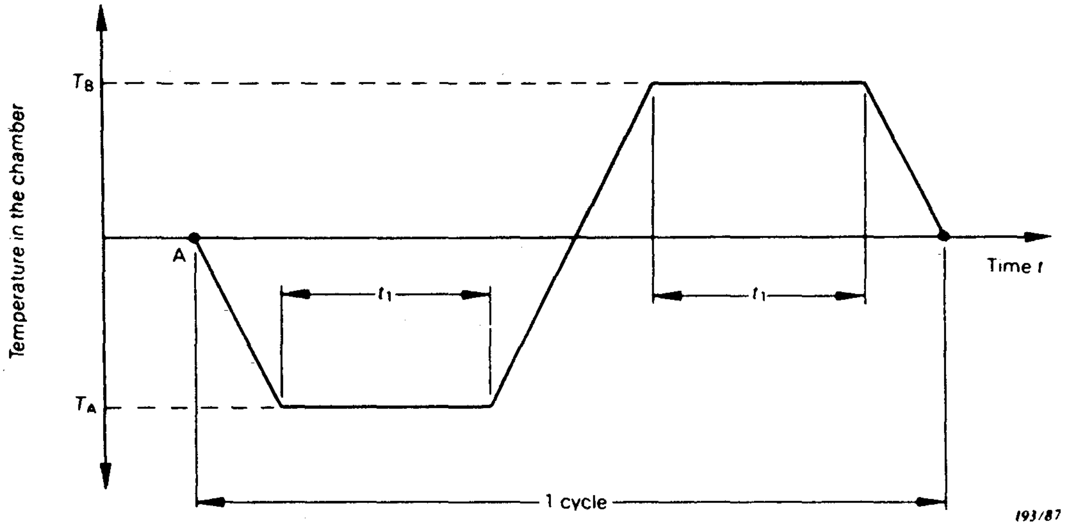
8) The sample shall be subjected to two cycles unless otherwise required in the relevant detail specification.

9) The relevant specification shall state:

   i) the change of attenuation and inspection checks during conditioning;

   ii) the period(s) after which they are to be carried out.

10) Before removal from the chamber, the sample under test shall have reached temperature stability at ambient temperature.



A = start of first cycle

Figure 11 - One cycle procedure

11) If the relevant specification indicates different temperature ranges for storage and usage instead of two different tests, a combined test procedure is allowed in accordance with figure 12.

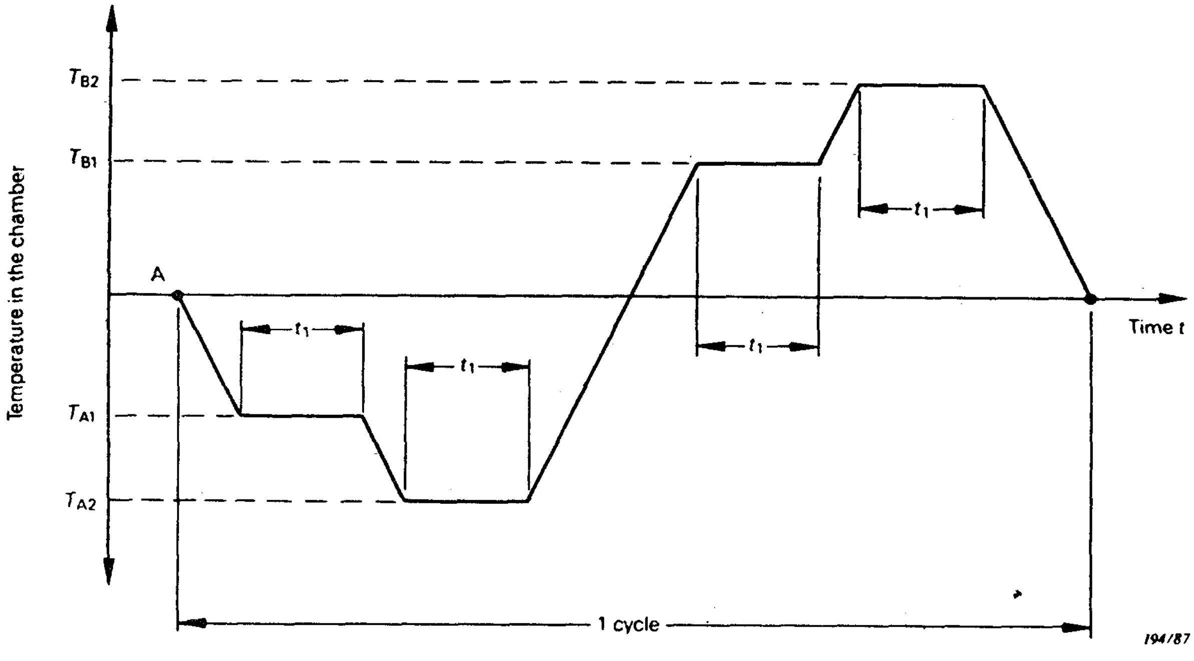


Figure 12 – Combined test procedure

12) The value of T_A, T_B and t_1 shall be specified in the detail specification.

The rate of cooling (or heating) shall be specified in the detail specification. Care should be taken that the temperature of the cable core does not significantly differ from the specified temperature of the climatic chamber at the end of the cooling (or heating) phases.

c) Recovery

1) If the ambient temperature is not the standard atmospheric condition to be used for testing after removal from the chamber, the sample shall be allowed to attain temperature stability at this latter condition.

2) The relevant detail specification may call for a specific recovery period for a given type of sample.

6.3.5 *Results*

a) Final measurements

The sample shall be visually inspected as well as optically and mechanically checked as required in the relevant specification.

b) The following data shall be presented with the results:

- diameter of the sample coil or reel;
- details of winding:
  - coil, reel, other (to be stated, in case of bufferized reel, the type of buffering used),
  - single or multilayer,
  - open winding or basket weave,
  - winding tension and zero tension facility device, if any,
  - type and materials of the holder,
  - position of the sample (vertical/horizontal);
- cable and fibre length under test. Type of connections between fibres (if any);
- end preparation;
- test set data including type of measurement equipment and launching conditions;
- severity of test (number of cycles, temperature cycle diagram). Temperature and times shall be recorded;
- if humidity is controlled or uncontrolled. If the humidity level is controlled, the humidity levels at each temperature extreme should be reported;
- change of attenuation at a specified wavelength as a function of temperature cycling including indication of accuracy.

6.4 Method IEC XXX-1-F2 – Contamination

For future consideration.

6.5 Method IEC 794-1-F3 – Sheath integrity

6.5.1 *Object*

This test method may be applied on unfilled outdoor cables to confirm that the cable sheath is continuous and free from holes. This may be done as an internal pressure test or, if the sheath is of the moisture barrier type, alternatively a spark test may be applied.

6.5.2 *Internal pressure test*

For unfilled cables the sheath shall withstand without leakage an internal gas pressure of 50 kPa to 100 kPa for 2 h after equalization of pressure throughout the cable length.

NOTE - It is not necessary to carry out this test if the sheath is tested in accordance with 6.5.3.

6.5.3 *Spark test (if applicable)*

The sheath shall withstand a spark test voltage of at least 8 kV r.m.s or 12 kV d.c.

NOTE - For unfilled cables, it is not necessary to carry out this test if the sheath is tested in accordance with 6.5.2.

6.6 Method IEC XXX-1-F4 – External static pressure

For future consideration.

6.7 Method IEC 794-I-F5 – Water penetration

6.7.1 *Object*

This test applies to completely filled outdoor cables with the intention to check that all the interstices of a cable are continuously filled with compound to prevent water penetration within the cable.

6.7.2 *Procedure*

Compliance shall be checked on samples of filled cable as follows (figure 13).

A circumferential portion of sheath and wrapping 25 mm wide shall be removed 3 m from one end of a sample length of cable and a watertight sleeve shall be applied over the exposed core so as to bridge the gap in the sheath.

The cable shall be supported horizontally and a 1 m head of water, containing a sufficient quantity of water-soluble fluorescent dye for the detection of seepage, shall be applied to the core for 24 h at a temperature of 20 °C ± 5 °C.

No dye shall be detected when the end of the 3 m length is examined with ultraviolet light.

NOTES

1 The test procedure mentioned above is a basic compliance requirement and for routine tests, samples of shorter length may be tested for a shorter time.

2 A cable should not be considered to have failed the test if within an occasional sample seepage (a few drops) of dye is detected outside the cable core and its wrapping.

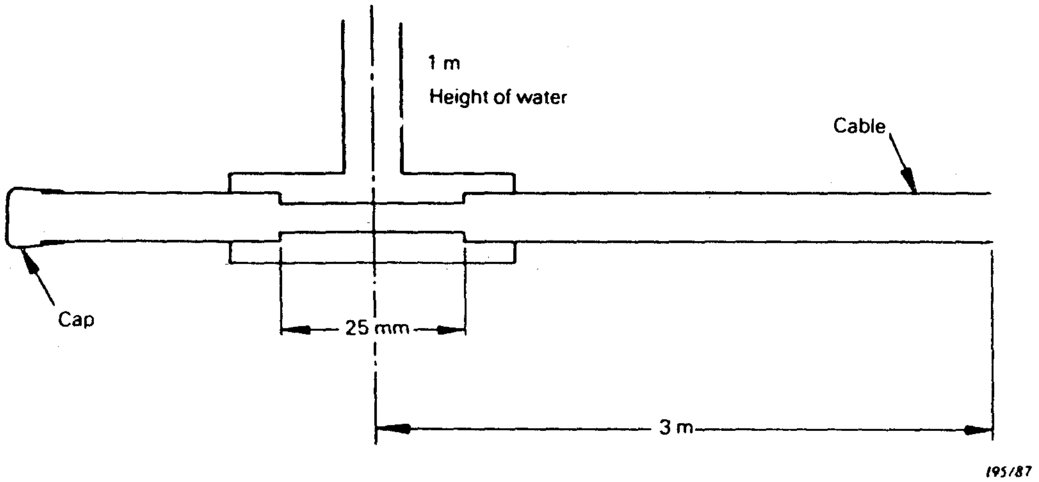


Figure 13 – Water penetration test

6.8 Method IEC XXX-1-F6 – Freezing

Under consideration.

6.9 Method IEC XXX-1-F7 – Nuclear radiation

Under consideration.

Annex A
(informative)

Guide for optical cables for short distance links

A.1 General

A.1.1 *Object*

This annex provides additional guidance relating to optical fibre cables for use in short distance links in communication equipment. It allows the establishment of uniform requirements for the geometrical, optical, transmission, mechanical and environmental properties of optical fibre cables.

A.1.2 *Reference documents*

IEC 793-1: 1992, *Optical fibres - Part 1: Generic specification*

IEC 793-2: 1992, *Optical fibres - Part 2: Product specifications*

IEC 794-2: 1989, *Optical fibre cables - Part 2: Product specifications*

IEC 874-1: 1987, *Connectors for optical fibres and cables - Part 1: Generic specification*

A.1.3 *Optical fibre categories*

Optical fibre cables used in short distance links shall be equipped with the following optical fibres:

A2 category: for distances of several hundred metres up to 2 km;

A3 category: for distances of a few hundred metres up to 1 km;

A4 category: for distances up to 100 m.

The characteristics of the optical fibres used shall be specified as stated in the relevant product specification.

A.2 Measuring methods for dimensions

NOTE - Measurements for optical fibre dimensions shall be carried out using the methods specified in IEC 793-1.

A.2.1 *Diameter measuring method*

The measuring methods for dimensions are given in table 1 of this standard and are applicable for optical fibre cables for short distance links.

A.2.2 *Length measurement*

This standard specifies two types of length measurements: either by mechanical means or by delay of transmitted and/or reflected pulses, as specified in IEC 793-1.

In the case of cable measurement on coil or reels, the second method (IEC 793-1-A6) can be used. Currently, a well-calibrated high resolution echometer would allow a precision of a few centimetres over a length of 100 m to be reached, for example.

A.3 Measuring methods for mechanical characteristics

When the cable is to be used without end connectors, the tests described in this standard are applicable.

When the cable is to be used with end connectors, tests are applied on the cable only and the combined tests on cable plus connector assembly are carried out according to IEC 874-1.

A.3.1 *Measuring methods for cable mechanical characteristics*

– Strippability	(under consideration)
– Tensile performance	(IEC 794-1-E1)
– Abrasion	(IEC 794-1-E2, under consideration)
– Crush	(IEC 794-1-E3)
– Impact	(IEC 794-1-E4)
– Repeated bending	(IEC 794-1-E6)
– Torsion	(IEC 794-1-E7)
– Flexing	(IEC 794-1-E8)
– Snatch	(IEC 794-1-E9)
– Kink	(IEC 794-1-E10)
– Cable bend	(IEC 794-1-E11)

A.3.2 *Measuring methods for connector mechanical characteristics*

– Dimensions	(IEC 874-1, clause 26)
– Drop	(IEC 874-1, sub-clause 28.17)
– Engagement and separation forces	(IEC 874-1, sub-clause 28.6)
– Mechanical endurance	(under consideration)
– Vibration	(IEC 874-1, sub-clause 28.2)
– Strength of coupling mechanism	(IEC 874-1, sub-clause 28.8)
– Strength of cable retention	(IEC 874-1, sub-clause 28.7)
– Cable torque	(IEC 874-1, under consideration)
– Effectiveness of fibre or ferrule retention	(IEC 874-1, sub-clause 28.4)

A.4 Measuring methods for transmission and optical characteristics

A.4.1 *Attenuation*

The cut-back technique with modified launching conditions described in the note below gives accurate results on short length fibres.

However, in the case of short fibre or cable measurement, the contribution of measurement error cannot be ignored because short fibre or cable loss is very close to the measurement error.

The insertion loss method can be used where accuracy is not important.

The high resolution backscattering technique as described in method IEC 793-1-C1C, may be suitable for A2, A3 and A4 category fibres.

NOTE - Non steady-state distribution.

In cases where fibre lengths are such that steady-state distribution is not achieved, launching conditions different from steady-state distribution are appropriate. In every case, where launching conditions are substantially different from steady-state conditions over the length of fibre to be measured, it is not possible to obtain attenuation coefficient values, i.e. the power distribution is not length independent. The measurement of the attenuation value under particular conditions can be specified. In this case, the conditions shall be reported, for example:

a) wavelength of the source;
b) spectral width;
c) radiation diagram;
d) length of fibre under test;
e) coupling between source and fibre under test;
f) specific launching conditions may be needed for other than attenuation measurements, for example full launch conditions as in item a) of 4.11.1 of IEC 793-1 (fourth edition).

It is recommended to use:

- a launching numerical aperture equal to or slightly greater than the maximum theoretical numerical aperture of the fibre under test;
- a launching light spot equal to or slightly greater than the core diameter of the fibre under test.

A generic launching arrangement to achieve the launching in short distance fibre is described in A.4.2

A.4.2 *Launching conditions*

As the reproducibility of the numerical aperture (NA) and attenuation measurements of step index fibres is critical, a well-defined launching set-up is necessary. Such a set-up can be achieved by using commercially available optical components and shall have the capability of providing a wide range of spot sizes and launch NA so as to cater for all types of fibres.

A.4.2.1 *Description*

The set-up produces the image of the source at the input end of the fibre under test. The diameter of the light spot and the maximum angle of the incident light at the input fibre end are respectively regulated by adjustable diaphragms 7, and 11, (figure A.1).

The actual spot size can be determined by the video screen using the reflected light from the fibre end and the beam splitter 8) (it is thus possible to align the centre of the light spot onto the centre of the fibre core).

Depending on the distance between the diaphragm 11) and the fibre end, the diaphragm is adjusted so as to obtain the desired maximum launching angle. Once this distance is fixed, its reproducibility is easily obtained because the fibre end must be in focus on the video screen.

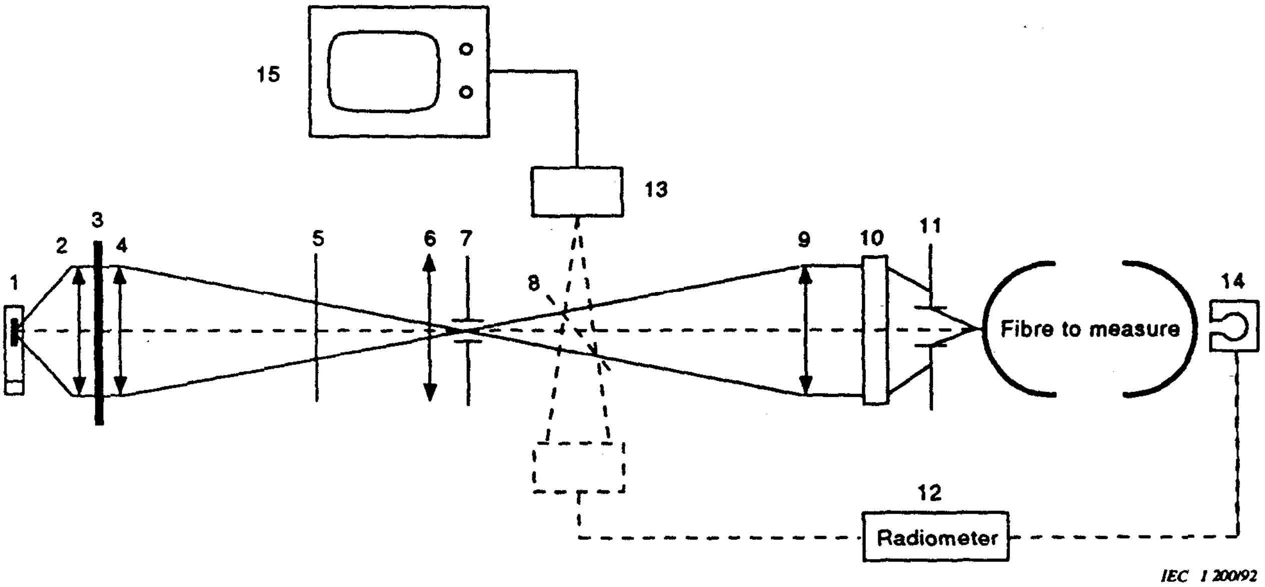
For A4 fibre, in order to obtain attenuation measurement without length dependance, it is recommended that a mode scrambler (see figure A.2 and table A.1) is placed between the fibre to measure and the diaphragm 11, and optical components 4 and 6 through 9, 13, 15 should be removed from the set-up. Spot size should be greater or equal to fibre core size and launching NA greater or equal to theoretical NA of the fibre to be measured. For numerical aperture measurements, further studies are needed.

A.4.2.2 *Test conditions*

To obtain reproducible NA and attenuation values, it will be necessary to specify:

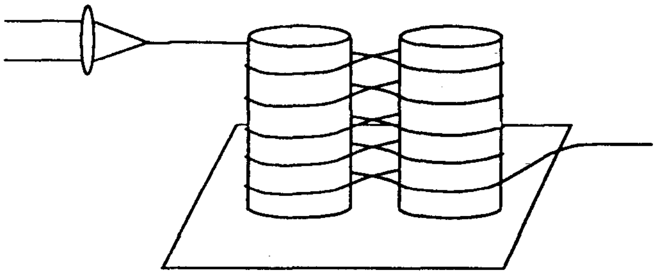
- spot size (percentage of the fibre core diameter);
- launch NA (percentage of the theoretical NA of the fibre);

- dimensions and number of turns of the mode scrambler, where appropriate.



1) Source (e.g. stip bulb 100 W)
2) Lens (e.g. Ø = 50,8 mm, F = 76,2 mm)
3) Filter (e.g. Ø = 50,8 mm, l = 850 ± 50 nm)
4) Lens (e.g. Ø = 50,8 mm, F = 76,2 mm)
5) Chopper
6) Lens (e.g. Ø = 50,8 mm, F = 125 mm)
7) Adjustable field diaphragm
8) Beam splitter
9) Lens (e.g. Ø = 50,8 mm, F = 500 mm)
10) Objective (e.g. F = 50–10,95)
11) Adjustable field diaphragm
12) Radiometer
13) Video monitoring
14) Detector
15) Video screen

Figure A.1



Mode scrambler

Figure A.2

Table A.1

Fibre diameter mm	Fibre length m	Diameter of cylinders mm	Distance between these two cylinders mm	Number of "8"-shaped turns
1,00	20	42	3	10
0,75	15	35	3	20
0,50	10	32	2	40

A.4.3 *Baseband response*

As far as bandwidths are considered, measurements by impulse techniques have been made on short lengths of A4 fibres.

Similar measurements for A2 and A3 fibres will be studied later.

A.4.4 *Optical continuity*

For both methods mentioned in table 3, it is recommended to use the transmitted or radiated light power method for short length fibres, IEC 793-1-C4.

A.4.5 *Numerical aperture*

It is recommended to use the far field distribution method (IEC 793-1-C6) with the modified launching conditions proposed for the attenuation measurement.

A.5 Measuring methods for environmental characteristics

A.5.1 *General*

When the cable is to be used *without* end connectors, the tests described in this standard are applicable.

When the cable is to be used *with* end connectors, tests are applied on the cable only and the combined tests on cable plus connector assembly are carried out according to IEC 874-1.

A.5.2 *Operating temperature range*

The usual temperature ranges encountered are:

from –40 °C to +65 °C (terrestrial applications)
from –55 °C to +85 °C (civil aircraft)
from –55 °C to +125 °C (military cables)
from –55 °C to +260 °C (aeronautic cables)

Appropriate fibre coatings shall be used.

A.5.3 *Measuring methods for cables*

– Fire test	(under consideration)
– Cold cable bend	(under consideration)
– Temperature cycling	(IEC 794-1-F1)
– Contamination	(IEC 794-1-F2, under consideration)
– Sheath integrity	(IEC 794-1-F3)
– External static pressure	(IEC 794-1-F4, under consideration)
– Water penetration	(IEC 794-1-F5)
– Freezing	(IEC 794-1-F6, under consideration)
– Nuclear radiation	(IEC 794-1-F7, under consideration)

A.5.4 *Measuring methods for connectors*

– **Climatic sequence**	(IEC 874-1, sub-clause 29.5)
– **Salt mist**	(IEC 874-1, sub-clause 29.9. Only for connectors with metallic parts)

Annex B
(informative)

Guide to the procurement of optical fibre cables

B.1 General

Procurement includes the entire process by which a purchaser can obtain optical fibre cable for a particular project. This process includes planning, selecting a product and vendor, pricing, arranging terms and conditions, issuing a proper contract or purchase order, ensuring timely delivery, acceptance, resolving problems and claims associated with such transactions, and quality assurance.

The procurement process should also perform a service function, aiding in cost reductions, even though it does not directly generate revenues. It should provide both long and short-range plans which meet the needs of the project in view of changes in technology, supply situations, and market conditions. Procurement can make significant contributions by providing forecasting and planning information to product and market developers in terms of material availability, lead times, new sources of supply, and technological innovations.

This annex is concerned with methods and procedures that are useful for the procurement of optical fibre cables and is intended to apply to the procurement process in general. All of the methods and procedures described may not be applicable to every purchasing case. Different purchasers will balance the size and cost of vendor qualification and product testing processes against the volume of their purchases and available resources.

B.2 Procurement steps

The following procurement steps are included to provide a typical procurement cycle for optical fibre cables, and to describe how the attached checklist is intended to be used.

B.2.1 *Planning criteria*

The first step in the process is establishing the criteria for the procurement of optical fibre cable, and seeking preliminary information.

B.2.1.1 *Optical fibre cable standards*

Wherever possible the product specification to be agreed upon should refer to published domestic, national, or international standards. Where none exist, the checklist shown in tables B.1 to B.6 may be used to develop an appropriate procurement specification.

B.2.1.2 *Request for information (RFI)*

Detailed information concerning specific parameters and features of the different vendor products can be obtained by submitting an RFI to potential vendors. In the RFI the customer may give a brief account of the intended usage and key points of requirements as a reference to manufacturers for exact response. RFI is often a preliminary step in the development of a procurement specification but it is not an absolutely necessary procedure if the customer already has enough technical and commercial information about certain vendors. In this case the RFI can be simplified, as appropriate.

The specification part of the RFI should contain a general statement of the work to be considered and specify only those parameters and requirements that are absolutely necessary.

B.2.1.3 *Request for quotation (RFQ)*

Seeking and selecting qualified suppliers comes after the RFI procedure and is a key aspect in the procurement process. In order to do this, responses to the RFI will come from potential vendors. The information received will result in further dialogue with the potential vendors, and ultimately in a final procurement specification. Once the final specification has been agreed upon, an RFQ is issued in order to select the best possible source for optical fibre cables.

B.2.2 *Purchasing and evaluation criteria*

Evaluation of quotations should include consideration not only of price, but also of such factors as delivery, terms and conditions, service, freight costs, vendor's financial position, training, and vendor quality rating.

B.2.3 *Contracts and purchaser orders*

A purchase award is usually made by issuing a contract or purchase order. This may vary in content so as to provide the most favourable conditions for the purchase.

B.2.4 *Quality and reliability assurance*

The basic responsibility for manufacturing products which conform to purchaser needs ultimately resides with the manufacturer. The ability of a manufacturer to do so depends on an existing, adequate quality management system which includes an ability to design cable to meet all functional requirements and an adequate programme for monitoring processes and products during manufacture.

B.2.5 *Acceptance measurements*

An acceptable minimum testing schedule must be agreed upon between manufacturer and customer, and established by the time of the order. All inspectors should be well trained and have the proper tools and equipment with which to make a judgement.

B.3 Optical fibre cable requirement checklist

The following tables offer a checklist to assist in developing a procurement specification for optical fibre cable. The units for each parameter will be found in the appropriate product specification for the fibre and/or cable. These tables may be used in the RFI, RFQ, and possibly other uses.

It should be emphasized that not all items in the following tables have to be specified. Over-specification can be costly and yet not provide any added value to the user. This is why the RFI and RFQ process should include enough repetitive steps to assure proper performance at the lowest practical cost. The checklist contains most items in as comprehensive a form as possible. When customizing this list for a particular application, all values and other information which are not necessary for satisfactory product performance should be deleted.

It is expected that this checklist will evolve into a procurement specification for a particular product.

Optical fibre cable requirements checklist

Table B.1 – General requirements

Fibre type:

Number of fibres:

Applications:

- Indoor:
- Outdoor:
- Category of fibre:
- Wavelengths:
- Temperature range for:
  - storage:
  - installation:
  - use:
- Other comments:
- (e.g.: User's name (optional))

Cable construction (to be determined only after study of application and other requirements):

Fibre protection:

- loose buffer:
- tight buffer:
- slotted core:
- other comments:

Colour coding:

Cable identification:

- user's name:
- manufacturer's name:
- fibre type:
- number of fibres:
- year of manufacture:
- length marking*:

Metallic conductors:

Outer protection/armouring:

- metallic or non-metallic construction:
- water-proof construction:

Other comments:

* First number is not necessarily zero.

Table B.2 – Dimensional requirements

Category of fibre (e.g. IEC 793-1, clause 1.4, and IEC 793-2):			
Fibre dimensional requirements (e.g. IEC 793-1, section 2):			
Parameter	Requirements/ specification	Test method	Comments
Diameter of core*			
Diameter of cladding			
Core non-circularity*			
Cladding non-circularity			
Core/cladding concentricity error*			
Other parameters:			
Diameter of coating			
Diameter of buffer			
Coating non-circularity			
Length of cable and tolerance			
Diameter of electrical conductor			
Thickness of insulation			
Thickness of sheath			
Overall cable dimension			

* Only applies to multimode fibre. Concentricity of mode field diameter (with respect to the cladding) of single-mode fibre is given in table B.4b.

Table B.3 – Mechanical requirements

Parameter	Requirements/ specification	Test method	Comments
Tensile strength			
Crush resistance			
Impact resistance			
Isostatic pressure			
Repeated bending			
Torsion			
Flexing			
Snatch			
Kink			
Bend			
Other mechanical requirements:			

Table B.4a – Transmission and optical requirements, multimode fibre in cable

Parameter	Operating wavelengths	Requirements/ specification	Test method	Comments
Attenuation				
Backscattering				
Baseband response/ bandwidth				
Numerical aperture				
Total dispersion				
Other requirements:				

Table B.4b – Transmission and optical requirements, single-mode fibre in cable

Parameter	Operating wavelengths	Requirements/ specification	Test method	Comments
Attenuation				
Backscattering				
Mode field diameter (MFD)				
Concentricity of MFD				
Chromatic dispersion				
Cut-off wavelength				
Other requirements:				

Table B.5 – Electrical requirements
(only required for hybrid cables)

Parameter	Requirements/ specification	Test method	Comments
Conductor resistance			
Dielectric strength of insulation			
Insulation resistance			
Other requirements:			

Table B.6 – Environmental requirements

Parameter	Requirements/ specification	Test method	Comments
Temperature cycling			
Performance under fire conditions			
Sheath integrity			
Water penetration			
Cold bend			
Freezing			
Nuclear radiation			
Other requirements:			

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